

Agricultural Research Service • National Program 305 • Crop Production
FY 2015 Annual Report



The Crop Production National Program (NP 305) supports research to develop knowledge, strategies, systems, and technologies that contribute to greater cropping efficiency, productivity, quality, marketability, and protection of annual, perennial, greenhouse, and nursery crops, while increasing environmental quality and worker safety.

The Nation's rural economic vitality depends on the ability of growers to profitably produce and market agricultural products including food, fiber, flowers, industrial products, feed, and fuels, while enhancing the natural resource base of crop production. Future financial success depends on increasing productivity, accessing new markets for specialized products, developing technologies to provide new opportunities for U.S. farmers, and utilizing tools and information to mitigate risks and enable rapid adjustments to changing market conditions. The farm sector has great and varied needs driven by a wide variety of resource, climatic, economic, and social factors that require an equally diverse array of solutions.

Contemporary cropping enterprises are complex and depend on highly integrated management components that address crop production and protection, resource management, mechanization, and automation. U.S. annual, perennial, and greenhouse (protected systems) crop production are based on the successful integration of these components. The development of successful new production systems requires a focus on new and traditional crops; the availability and implementation of improved models and decision aids; cropping systems that are profitable and productive; production methods fostering conservation of natural resources; efficient and effective integrated control strategies for multiple pests; improved methods, principles, and systems for irrigation; improved mechanization; and reduced inputs – all while sustaining or increasing yield and quality.

Production systems must better address the needs of small, intermediate, and large farming enterprises including those using field-, greenhouse-, orchard-, and vineyard-based production platforms with conventional, organic, or controlled environment strategies. Additionally, adaptation and/or development of technologies are/is required to ensure a sustainable and profitable environment for production agriculture. New technologies must address the need for lower cost, higher efficiency inputs that foster conservation of energy and natural resources, while maintaining profitability and promoting environmental sustainability.

In addition, declining bee populations and honey production require special attention. Over the past several years, a myriad of pests and potentially adverse cultural and pest management practices have been threatening many of the bee species required for pollination of multitudinous crops. Colony Collapse Disorder has increased honey bee (*Apis*) over-wintering mortality to over 30 percent. Also, as new crops or niches are introduced, there is an increasing need for non-honey bee pollinators for specific crops or protected environments.

National Program 305 coordinates and collaborates extensively with other ARS National Programs, universities, and industries in adapting and incorporating technologies, approaches, and strategies that enable the advancement of the Nation's agricultural industry and enhanced international competitiveness. The current Action Plan (2013-2018) can be viewed online at

http://www.ars.usda.gov/research/programs/programs.htm?np_code=305&docid=22848.

This National Program is divided into two main research components, with several Problem Statements:

- **Component 1: Integrated Sustainable Crop Production Systems**
 - *Problem Statement 1A*: Productive and Profitable Systems for Sustainable Production of Agronomic Crops
 - *Problem Statement 1B*: Productive and Profitable Systems for Sustainable Production of Temperate Fruit and Nut Crops
 - *Problem Statement 1C*: Productive and Profitable Systems for Sustainable Production of Tropical and Sub-Tropical Crops
 - *Problem Statement 1D*: Productive and Profitable Systems for Sustainable Production of Ornamental, Nursery, and Protected Culture Crops
 - *Problem Statement 1E*: New and Improved Mechanization
- **Component 2: Bees and Pollination**
 - *Problem Statement 2A*: Bee Management—Improving Bee Nutrition and Performance
 - *Problem Statement 2B*: Bee Health—Mitigating the Impacts of Pathogens, Pests, and Pesticides
 - *Problem Statement 2C*: Maximizing Bee Pollination and Quantifying Bee Forage Requirements
 - *Problem Statement 2D*: Conserving Bee Diversity and Improving Bee Taxonomy

Below are National Program 305 accomplishments from fiscal year 2015, grouped by research component and problem statement. This report is not intended to be a progress report describing all ongoing research, but rather an overview that highlights accomplishments, some of which are based on multiple years of research (not all research projects will reach an “accomplishment” endpoint each year).

ARS welcomes your input regarding our ongoing research programs. If you have any questions, please do not hesitate to contact the co-leaders of National Program 305, Kevin Hackett (Kevin.Hackett@ars.usda.gov) and Gail Wisler (Gail.Wisler@ars.usda.gov).

Component 1 – Integrated Sustainable Crop Production Systems

Problem Statement 1A: Productive and Profitable Systems for Sustainable Production of Agronomic Crops

Sugarcane yield monitor increases harvest efficiency and profitability. A commercially acceptable yield monitoring system is not currently available for sugarcane harvesters. ARS scientists in Houma, Louisiana, working with Louisiana State University cooperators, developed and tested a new optical yield monitor for use on a billet type sugarcane harvester. The system uses three lasers mounted on the top of the harvester elevator and measures the cane yield directly in the field. A calibration equation that was developed with data from the monitor indicated the amount of cane on the elevator, harvested distance, harvester speed, and direction of cut, all significantly correlated with weight. On larger truck loads (over 60 metric tons), the system predicted loads with errors below 2 percent. The system is currently under commercial testing at several sugarcane farms throughout Louisiana. The yield monitoring system will help sugarcane growers better manage their fields with the ultimate goal of growing better yielding crop and increasing profits.

Winter camelina dual-cropped with soybean used as a “cash” cover crop provides environmental benefits. Competition between growing biofuel and food crops on agricultural lands has been a growing cause of concern so ARS researchers in Morris, Minnesota, looked at methods of producing both on the same land in a single season. The researchers demonstrated that winter camelina used as a “cash” cover crop for biofuel feedstock can be sustainably dual cropped with soybean in the Corn Belt (of the Midwestern United States). Results showed that interseeding (a.k.a. “relay-cropping”) soybean into winter

camelina in the spring led to combined seed yields that were economically competitive with a single full-season soybean crop. Moreover, a camelina-soybean dual crop system, which adds a cover crop to the rotation, offers environmental benefits such as reduced soil erosion and sequestration of nitrogen and phosphorus that a simple corn-soybean rotation does not.

Problem Statement 1B: Productive and Profitable Systems for Sustainable Production of Temperate Fruit and Nut Crops

Drip irrigation helps to improve the health benefits of blueberries. In most countries, including the United States, drip irrigation has rapidly become the most popular method to irrigate blueberries. An ARS scientist in Corvallis, Oregon, determined that young blueberry plants often grow better with drip irrigation than with conventional sprinkler systems, but little information was available on the use of drip irrigation in mature plantings. In cooperative work with Agriculture and Agri-Food Canada, researchers found that blueberry plants became more sensitive to soil water limitations with age and required more irrigation to have profitable production. Antioxidants in the fruit were also higher with than without drip irrigation, and therefore, drip irrigation, if properly managed, could help to improve the health benefits (increase antioxidants) of blueberries. This information was used to develop new irrigation guidelines for highbush blueberry, which have been adopted by the industry to improve production and quality in the Pacific Northwest.

Calcined kaolin particles mitigate ozone damage in apple. As ozone levels are positively related to air temperature and growing season temperatures are expected to increase due to climate change, ozone levels will rise. ARS scientists in Kearneysville, West Virginia, studied calcined kaolin applied to apple trees over a 6-year period and evaluated fruit yield and quality and ambient ozone levels. The calcined kaolin particles catalyzed the degradation of ozone and stimulated non-pathogenic microbial populations on the leaf surface, which further increased ozone degradation and increased apple quality. The use of calcined kaolin may be one tool to mitigate increased ozone stress.

Problem Statement 1C: Productive and Profitable Systems for Sustainable Production of Tropical and Sub-Tropical Crops

Improved diagnostic reliability for detection of the presumed causal agent of citrus greening. Reliable detection and quantification of *Candidatus Liberibacter asiaticus* (CLas, presumed agent of citrus greening) is crucial for regulatory management strategies to prevent epidemics. Sensitivity of the standard assay protocol (quantitative polymerase chain reaction or qPCR) is constantly challenged, but without data to support the challenges. ARS scientists in Fort Pierce, Florida, conducted experiments to test the effects of various assay parameters on qPCR detection of CLas. The results demonstrated that the test used and validated by APHIS to detect citrus greening was accurate enough to detect as few as one bacterial cell, whether from citrus or the Asian citrus psyllid vector. However, the scientists improved the parameters of the assay test by reducing the chance of false negatives, thus improving the reliability of the test. Considering the immediate threat of citrus greening to the California citrus industry and the danger posed by false negative diagnoses of *Liberibacter*, these results have considerable significance. Based on the research, APHIS has incorporated these changes into their test protocols for *Liberibacter*.

Improvement of drought resistance in horticultural crops. Drought is a major abiotic stress constraining agricultural production. Plants have evolved diverse strategies to respond to drought and increased abscisic acid (ABA) concentrations by closing stomates to reduce transpiration. An ARS researcher in Davis, California, in collaboration with researchers at the University of California, Davis, produced transgenic petunias containing a tomato gene which increases ABA levels and is switched on only under drought

stress. The plants were not only resistant to severe drought, but fully recovered when water stress was lifted, and showed no negative effects under normal conditions. The research may lead to successful development of drought-resistant horticultural crops.

Drought resistance of grapevine rootstocks is associated with greater water permeability of fine roots.

Water deficits are known to alter fine root structure and function, but little is known about whether drought-resistant grapevines undergo these anatomical and biochemical changes. ARS researchers in Davis, California, evaluated how prolonged and repeated drying cycles affected fine root anatomy and hydraulic permeability in rootstocks known to differ in drought resistance. Drought resistance was associated with root traits that maintained a higher capacity for water uptake through reduced suberization (formation of a corky impermeable layer); i.e., less suberized roots absorbed more water. These research efforts provide a better understanding of drought resistance in grapevines, which will enable development of precision irrigation strategies tailored to these traits and identification of tools to more rapidly evaluate germplasm collections and identify drought-tolerant genotypes.

Yield performance and bean quality of cacao propagated by grafting and somatic embryo-derived cuttings.

Twelve cacao (*Theobroma cacao*) clones propagated by grafting and orthotropic rooted cuttings of somatic embryo-derived plants were grown on Ultisol soil in Corozal, Puerto Rico, for 6 years of production under intensive management and evaluated by ARS scientists in Mayaguez, Puerto Rico. Propagation treatments had a significant effect on dry bean yield and pod index but not on number of pods produced. Dry bean yield of varieties propagated by grafting was 7 percent higher than those propagated by orthotropic rooted cuttings of somatic embryo-derived plants. This yield difference could not be attributed to grafted plants being more vigorous nor by differences in root architecture. With few exceptions, flavor characteristics were not significantly affected by propagation treatments. This study proves that the use of somatic embryogenesis is a viable propagation system for cacao. This is the first study reporting long-term production data, which compares yield performance and quality traits of cacao trees propagated by grafting.

USDA California Climate Sub Hub built capacity and partnerships to meet its mission. The California Climate Sub Hub developed communication networks to complement and leverage existing efforts, including an assessment of the State's agricultural vulnerabilities to climate change and identification of adaptation and mitigation options to support "Building Blocks for Climate-Smart Agriculture." An advisory committee was created with USDA, state government agencies, and university colleagues to develop the Climate Sub Hub's strategic plan. The Sub Hub and Colorado State University collaborated to expand COMET-Farm, the greenhouse gas accounting tool from the USDA-Natural Resource Conservation Service (NRCS) for California's specialty crops. The Sub Hub prepared a vulnerability assessment for a special issue of Agriculture, Ecosystems, and the Environment; initiated a comprehensive vulnerability assessment of California rangeland involving federal, state, and industry partners; and updated the Forest Stewardship report with the University of California's Division of Agriculture and Natural Resources. Combined, these efforts facilitate the ability of ARS to deal with climate change in a proactive science-based manner.

Problem Statement 1D: Productive and Profitable Systems for Sustainable Production of Ornamental, Nursery, and Protected Culture Crops

Steel slag can be effectively used as a component in soilless container media to adjust pH and provide beneficial silicon and some nutritional elements. Soilless growing media, typically used in containerized production, generally has a low initial pH and contains minimal nutrition for plant growth. Steel slag, a by-product of the steel manufacturing industry, has been used to elevate field soil pH and is associated with elevated plant nutrition. ARS researchers in Toledo and Wooster, Ohio, demonstrated that media pH can

be adjusted utilizing steel slag as a substitute for dolomitic lime in soilless growing systems. In addition, some nutritional benefits can be realized, including elevation of silicon, but these inputs were insufficient to eliminate the use of additional fertilization, especially for microelements. However, with careful management, the use of steel slag could enable greenhouse and nursery growers to reduce fertilizer inputs resulting in less environmental contamination.

PhotoSim developed as a decision-support tool for plant production in protected horticulture systems.

Plant photosynthetic rate is impacted by light intensity, CO₂ concentration, and temperature but growers' decisions about these parameters are often made without an understanding of how they impact photosynthetic rate and plant growth. ARS scientists in Toledo, Ohio, developed single-leaf photosynthetic response curves for popular bedding and potted crop species in response to light, temperature, and CO₂. The data were modeled and packaged into a decision-support software tool called PhotoSim that provides growers the ability to estimate the impact that changing one of these parameters will have on plant growth, thereby allowing them to better manage the greenhouse or protected horticulture environment, improve plant growth, and reduce production costs.

Problem Statement 1E: New and Improved Mechanization

Assessment and control of spider mite damage in cotton via multispectral imaging. Spider mites can cause significant damage in cotton, resulting in significantly decreased yields. ARS researchers in College Station, Texas, used a multispectral optical sensor to quantify spider mite damage in cotton, showing that half-rate application of common acaracides was just as effective as full-rate applications in controlling mites. Farmers, crop consultants, and applicators will be able to use the results of this work to reduce the use of chemicals and environmental loading while maintaining good control of these cotton pests.

Computer controlled premixing inline injection system saves ingredients ensuring efficiency of variable-rate sprayers. Conventional sprayers in ornamental nurseries and orchards are grossly inefficient because the same amounts of chemicals are constantly discharged to the field regardless of plant presence, canopy structure, or leaf foliage density. New air-assisted, variable-rate spray technologies developed by ARS researchers in Wooster, Ohio, offer a promising solution, however, the new spraying systems have problems with excessive tank mixture leftover. To overcome this challenge, ARS researchers in Wooster, Ohio, developed an automatic real-time premixing inline injection system that stores water and chemical concentrates separately, in different tanks, and mixes them directly in spray lines. The new inline injection system is able to maintain consistent chemical concentrations for the variable-rate precision sprayers with a wide dynamic range of spray outputs and avoids long lag time, inconsistent mixture uniformity, and inaccurate chemical flow rate usually associated with conventional direct inline injection systems, resulting in further improvement of spray application efficiency and environmental stewardship for variable-rate precision sprayers.

Development of a dedicated environmental control system to measure semiochemical release rates.

Applications of semiochemicals to attract or repel insects or to disrupt their mating have increased rapidly as a pest management strategy. Because they are safer and have minimal non-target impacts, they have been integrated with other disciplines to provide reliable and eco-friendly pest management tools for effective pest control. However, predictions of their longevity are currently hampered due to a lack of sophisticated methods to accurately monitor how the primary variables affect the semiochemical release rate. ARS researchers in Wooster, Ohio, developed an environmental system that was able to control the air temperature and relative humidity to accurately measure semiochemical release rates. Test results verified that measurements of release rates of three semiochemicals in the controlled environmental system were more precise, consistent, and repeatable than measurements under field conditions.

Consequently, using the new system to precisely quantify semiochemical release rates for different temperatures and relative humidities will provide baselines for modelling semiochemical longevity under field conditions, deployment of semiochemicals, and optimization of design of semiochemical release devices.

Pesticide rates established for control of brown marmorated stink bug (BMSB). The brown marmorated stink bug (BMSB) is a new, major pest threatening horticultural crops. ARS researchers in Kearneysville, West Virginia, developed effective short-term mitigation strategies, i.e., insecticide applications, for management of BMSB in tree fruit. Information generated from this ARS effort has been published in guides for managing specialty crops including: the Virginia, West Virginia, and Maryland 2015 Spray Bulletin for Commercial Tree Fruit Growers; the 2015 New Jersey Tree Fruit Production Guide; and the 2015 Pennsylvania Tree Fruit Production Guide. Adoption of recommendations for BMSB is estimated to have been used on about 50,000 acres of tree fruit in the mid-Atlantic region.

Component 2 – Bees and Pollination

Problem Statement 2A: Bee Management—Improving Bee Nutrition and Performance

Changes in honey bee gut bacterial communities can cause health problems. Diet can often affect honey bees' gut microbiota leading to health problems. ARS scientists in Tucson, Arizona, found that a common pollen supplement, Megabee, fed to honey bees during pollen dearth did not affect the diversity or abundance of gut bacterial communities at 3 or 7 days post bacterial inoculation. This provides clear evidence that the transmission of core gut bacteria by honey bees does not rely on contact with older nest mates as previously speculated. Moreover, bacterial succession in the gut is highly resilient to changes in the nutritional environment, suggesting that selection by the host's gut is the most critical determinant of gut bacterial colonization in honey bees. These results suggest that artificial pollen supplements are unlikely to affect bee health via alteration of the gut bacterial community.

Brood production in honey bee colonies can be estimated using continuous temperature data. The amount of brood in a bee colony is an important indicator of colony health and queen status. ARS researchers in Tucson, Arizona, monitored temperature and brood production within honey bee hives and linked daily temperature variability to the amount of brood the bee colony produced. By placing a temperature sensor near the top middle of the bottom box, bee researchers and beekeepers can reliably estimate the amount of brood without disturbing the hive.

Varroa mite fall migration significantly increases mite levels in honey bee colonies. Varroa is the most serious pest of honey bees and a leading cause of colony loss during winter. ARS researchers in Tucson, Arizona, documented that these mites migrate into colonies on foraging bees. The highest levels of migration are in the fall, causing mite populations to be higher than expected, particularly following late summer miticide treatments. These findings indicate that beekeepers need to monitor mite levels until foraging ends (due to low temperatures). Multiple fall miticide applications may be needed to keep mite levels low enough for bee colonies to survive over the winter.

Bumble bee pollen diet is more restricted than honey bees. To preserve bee diversity during land restorations, better knowledge of bee plants is needed. ARS researchers in Logan, Utah, with Utah State University collaborators, found that in both weekly and across-the-season samples, bumble bees forage for less diverse sources of pollen than co-located honey bees. However, individual bumble bees were more likely to visit multiple pollen sources within a foraging trip than individual honey bee workers. Thus, pollen diet requirements for floral provision strips on crop land should be sufficiently broad to feed multiple

species of bees. This information will be useful for land managers in land reclamation efforts where they wish to ensure a sufficiently diverse food source for a variety of bees.

Bee hive-specific bacteria increase larval survival. Bee larvae are the target for a variety of disease organisms. Putatively beneficial bacteria, *Lactobacillus kunkeei* and *Acetobacteraceae* (Alpha 2.2) are found in larval guts, the brood food produced by nurse bees, the glands that produce this jelly, and the nurse bee foregut. ARS scientists in Tucson, Arizona, discovered that one of the bacteria, Alpha 2.2, increased larval survival. Both of these bacteria are honey bee hive residents but a wide variety of closely related strains occur worldwide in flowers and the food stores of many different pollinator species. Overall these results indicate that bacteria can have a positive effect on honey bee health and highlight the need for context driven investigations at the level of the hive environment and pollination landscape.

Stored pollen is not evolved for microbial nutrient conversion. Nutrition is a critical component of honey bee health and long thought to be influenced by microbially-mediated nutrient conversion of stored pollen. ARS scientists in Tucson, Arizona, found that honey bees prefer to consume freshly-collected pollen over aged (stored) pollen. Bacterial number decreased with pollen storage time and with a consideration of surface area, was generally insufficient to mediate nutrient change. Bacterial communities were similar, according to pollen storage age and colony origin, but differed significantly by sampling season. Despite the presence of many bacteria capable of digesting complex plant polymers, microscopy revealed the conspicuous absence of compromised pollen grains and fungal hyphae in all pollen samples regardless of pollen age or season. These results indicate that stored pollen is not evolved for nutrient conversion, but is largely preserved via the same mechanisms as is honey.

Problem Statement 2B: Bee Health—Mitigating the Impacts of Pathogens, Pests, and Pesticides

Genomics allows targeting of sensitive immune proteins in bees. Honey bees are attacked by a large number of pathogens, however little is known about their immune response. Through collaborative work with an international consortium from 30-plus institutions, ARS researchers in Beltsville, Maryland, sequenced the full genome of two Asian honey bee species; the North American bumble bee species used most for commercial pollination, *Bombus impatiens*; and the Alfalfa leaf cutting bee. This work helped identify genes associated with the behavioral-and disease-related traits of these species, and develop insights into social behavior and key biology traits. Researchers can now target genes for immune proteins that are especially responsive to disease agents. This information will eventually be used for the management of pollinator species in croplands and to improve management strategies for better bee health.

Characterization (new species identified) of a widespread gut parasite of honey bees led to industry analyses of its impact on bee health. ARS scientists in Beltsville, Maryland, determined that the primary trypanosomatid parasite of honey bees was misidentified, causing confusion about bee disease. To improve the understanding of bee parasites and their biology a new genus and species were named, using extensive collections, as well as genetic and microscopic insights. This result has enabled worldwide studies of this parasite, pointing to an unappreciated role in bee declines. The new species has been recognized by the beekeeping and regulatory community and has led to renewed analyses of disease collections to determine its impact on bee health worldwide.

Relational database created for world-class bee reference collection and made available online. Essential information on the biology and distribution of native bees is needed both for managing bees and conserving them and the services they provide. Institutional collections of bees are invaluable resources for ascertaining the status of the pollinators essential for successful reproduction of plants in agricultural

and natural environments. ARS houses the U.S. National Pollinating Insects Collection in Logan, Utah, the largest collection of bees in the world, containing approximately 1.4 million specimens from 136 countries. Data from the insect labels, including the identity, date and time of collection, host plant, and gender, was entered into a specimen-level relational database which now totals 1,108,677 records. This reference collection is visited and used by scientists from all over the world, and the data on pollinators is made available to the public and the scientific community through the Global Biodiversity Information Facility and Discover Life websites.

Discovery that Alpine bumble bee populations represent genetically distinct island-like populations inform land management decisions and species conservation measures. An ARS scientist in Logan, Utah, led team of collaborators at Utah State University and Washington State University demonstrated that bumble bee species restricted to high elevation sites in Olympic National Park, North Cascades National Park, and Mount Rainier National Park each have distinct genetic structure. Degradation of alpine habitat through global climate change could further fragment populations, reducing gene flow among the parks. Additionally, models of climate suggest that suitable habitat will decrease for several bumble bee species, while low elevation species should see an increase in habitat. These results have been shared with the National Park Service for use in interpretive material in the parks and to inform land management decisions and species conservation measures in the parks.

Problem Statement 2C: Maximizing Bee Pollination and Quantifying Bee Forage Requirements

New “Pollinator Research Action Plan” released by the White House. Pollinator health is a crucial component of managed and natural landscapes. Pollinator populations have drastically declined in recent years due to a number of issues; some issues associated with agricultural practices need further study. In June 2014 President Obama issued a mandate establishing a task force that would develop a strategy to promote the health of honey bees and other pollinators. As a result of this mandate an ARS researcher in Morris, Minnesota, co-authored the "Pollinator Research Action Plan," which was published and released by the White House in May 2015 and has a "roadmap" for federally-supported pollinator health research to help prioritize where and how federal funds are used for pollinator research.

Problem Statement 2D: Conserving Bee Diversity and Improving Bee Taxonomy

Improved cryopreservation of honeybee spermatozoa with new USDA Honeybee Extender Medium. To establish a honeybee germplasm repository, a standardized spermatozoa protocol is needed. Current efforts to cryopreserve honeybee spermatozoa use Harbo Extender Medium; while it does produce viable spermatozoa after cryopreservation, efficacy is limited because it is based on mammalian spermatozoa physiology. ARS researchers in Fargo, North Dakota, recently developed an improved extender medium, basing it on insect spermatozoa physiology, the USDA Honeybee Extender Medium. Although the improvement to survival immediately after storage is modest (70-80 percent survival for Harbo Extender Medium vs. about 90 percent for USDA Honeybee Extender Medium), the effects on sperm longevity after storage are more profound. While spermatozoa preserved with Harbo Extender Medium rapidly succumb at room temperature, more than 75 percent of those preserved in USDA Honeybee Extender Medium remain viable even after 6 months at room temperature. This is critical to the practical success of a honeybee germplasm repository. Honeybee queens store spermatozoa for extended periods of time after insemination in their spermatheca, and if a queen is storing unviable sperm this will result in the rapid demise of her colony.